Liquid Scintillator for NOνA

Stuart Mufson
Indiana University

Fermilab

November 16, 2006

Liquid Scintillator for NOνA

- NOνA's fiducial mass is dominated by its active detector medium – liquid scintillator
- NOνA is very large so it needs a very large mass of liquid scintillator

The NOνA detector requires 14.8 kilotons of liquid scintillator

- Requirements: the NOνA liquid scintillator must
  - be affordable
  - meet light yield and attenuation length requirements set by NOνA science
  - have a production and delivery schedule that matches the NOνA far detector construction
  - be delivered to the NOνA far detector with assurances that its quality keeps construction on schedule
  - minimize environmental hazards

Indiana Homebrew -- Composition

Bicron and Eljen Technologies, commercial producers of liquid scintillator, declined to bid on NOνA scintillator

- we must produce our own

NOνA plans to use a liquid scintillator equivalent to Saint-Gobain (Bicron) BC-517P or Eljen Technology EJ-321P

Composition

component		mass fraction
mineral oil	**liquid**	**94.4%**
pseudocumene	**liquid**	**5.5%**
PPO	**powder**	**0.1%**
bis-MSB	**powder**	**0.002%**
Stadis-425 (anti-static)	**liquid**	**0.0002%**
Total		**100.0%**

1. **mineral oil -- solvent**
2. **pseudocumene -- primary scintillant**
3. **PPO/bis-MSB -- waveshifters**
4. **Stadis-425 -- anti-static agent**

Indiana Homebrew -- Composition

Quantities of components required:

component	volume (gal)	tot mass (kg)
mineral oil	4,350,259	13,997,392
pseudocumene	245,306	813,440
PPO		17,901
bis-MSB		251
Stadis-425		29.7
Total	**4,595,565**	**14,829,014**

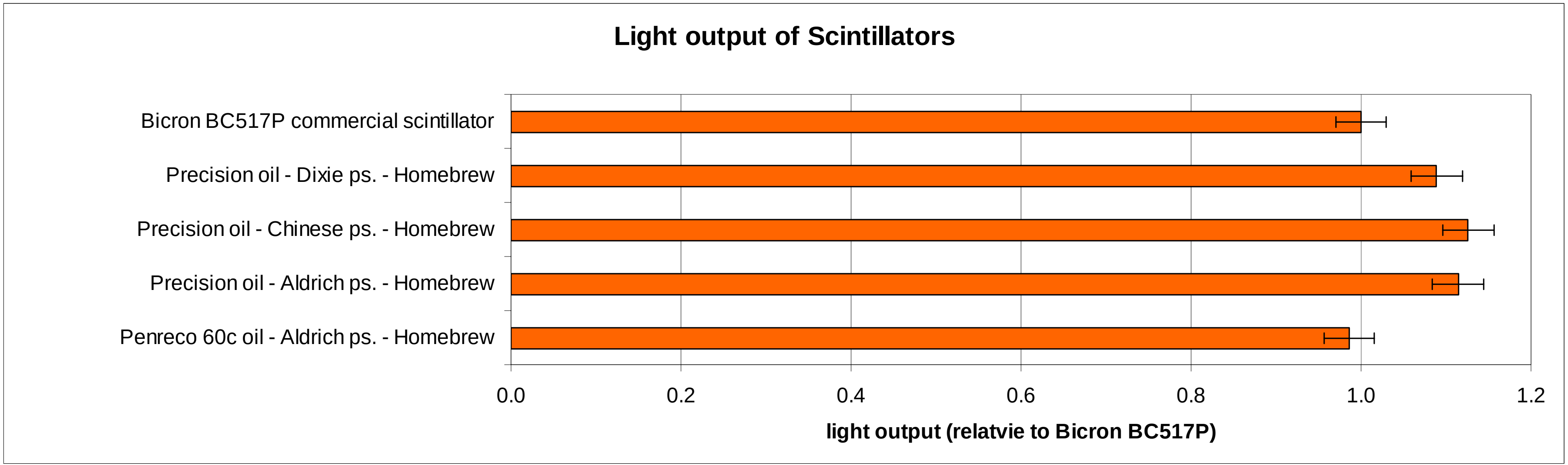
Fermilab has solicited and received hard quotes on these components

Delivery Schedule

Start	End	# months
March, 2010	May, 2013	38

Indiana Homebrew -- Light Yield

Light yield of IU Homebrew made with bid samples of {mineral oil, pseudocumene, & waveshifters} compared with commercial baseline BC517P



Blending

Blending Model:

- **Components**
  - **mineral oil delivered to scintillator oil mixing facility or nearby storage facility**
    - **tanker trailer/ ISO tanker/rail/barge all being discussed**
  - **scintillants delivered to scintillator oil mixing facility**
    - **pseudocumene delivered from chemical supplier by truck or rail**
    - **waveshifters (PPO + bis-MSB) delivered prepackaged from manufacturer**
- **Blending options being considered**
  - **blending at Fermilab**
  - **blending at commercial toll blending facility**
    - **commercial blending in Chicagoland or within a one day truck drive to Ash River**

Blending

Blending Model:

- **QC**
  - **QC incoming components arriving at the blending facility**
  - **QC outgoing blended scintillator as it leaves the blending facility**
  - **QC blended scintillator at Ash River**
  - **QC tests**
    - **mineral oil**
      - **compliance with attenuation length spec**
      - **compliance with density and water content spec with certified test report from the producer**
    - **pseudocumene**
      - **purity as tested at Indiana U**
      - **clarity (Pt-Co test)**
    - **waveshifters**
      - **tests by Anna Pla-dalmau at Fermilab**
    - **blended scintillator**
      - **compliance with attenuation length spec**
      - **compliance with light yield spec**

Blending

- Tolerances on blended liquid scintillator
  - Blended liquid scintillator shipped to Ash River in tanker trucks

Composition and tolerances per 6,500 gal tanker truck of blended scintillator

component	weight/mass per 6,500 gal	tolerance by weight	weight/mass tolerance per 6,500 gal
mineral oil	43,650 lbs	1%	435 lbs
pseudocumene	2,540 lbs	1%	26 lbs
PPO	25.3 kg	1%	250 gm
bis-MSB	355 gm	1%	3.5 gm
Stadis-425	42 gm	1%	0.5 gm

QC -- Attenuation Length

Lovibond tintometer makes transmission measurements at 410nm, 420nm, 430nm, 440nm, 450nm, 460nm through a 6" glass cell

Method:

- **measure transmission of "known" standard**

$$T_s = T_0 \exp(-L_c/\lambda_s)$$

- **measure transmission of "test" oil/scintillator sample**

$$T_t = T_0 \exp(-L_c/\lambda_t)$$

$$\Rightarrow \qquad \lambda_t = \left[\frac{1}{\lambda_s} + \frac{1}{L_c}\ln\left(\frac{T_s}{T_t}\right)\right]^{-1}$$

T_s = transmission of standard measured by tintometer

T_t = transmission of test sample measured by tintometer

T_o = transmission after losses due to cell (reflections, scattering, etc.)

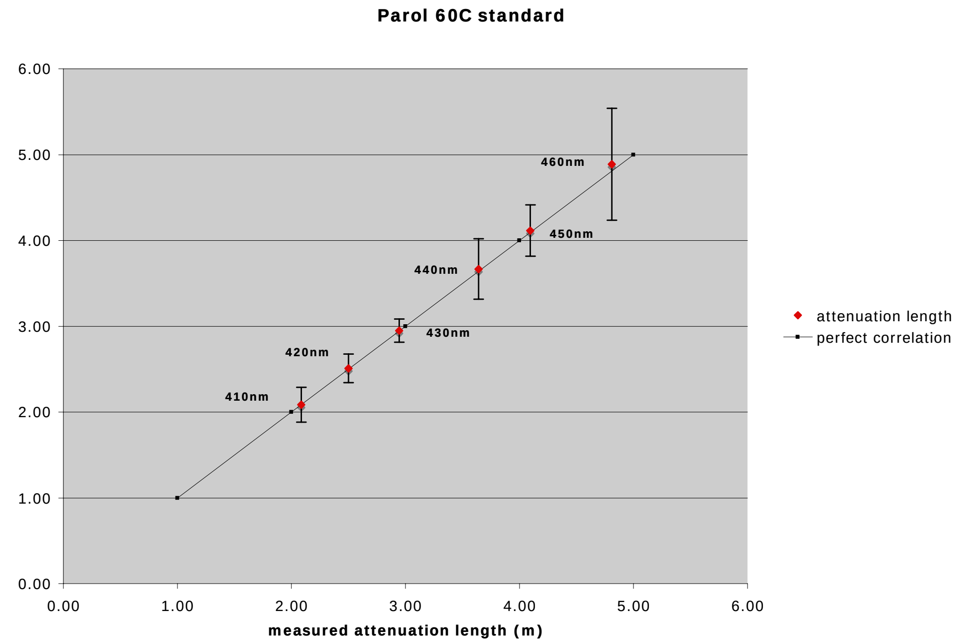
λ_s = attenuation length of standard

λ_t = attenuation length of test sample

L_c = cell length = 6"

QC -- Attenuation Length

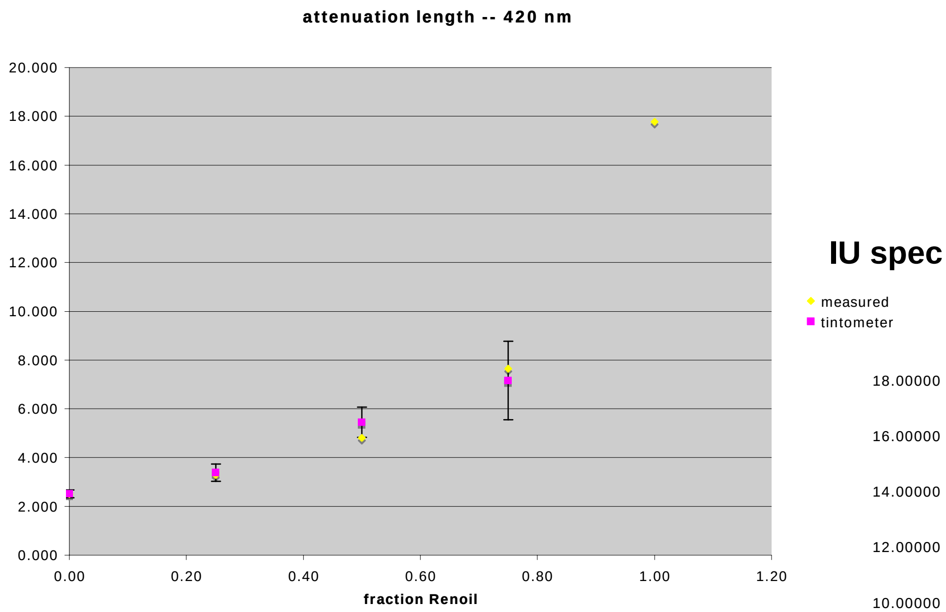
- method requires accurate knowledge of the standard
  - ❖ measured attenuation length compared with 12 tintometer determinations of the attenuation length
  - ❖ average of 12 tintometer measurements shown
  - ❖ errors taken as r.m.s

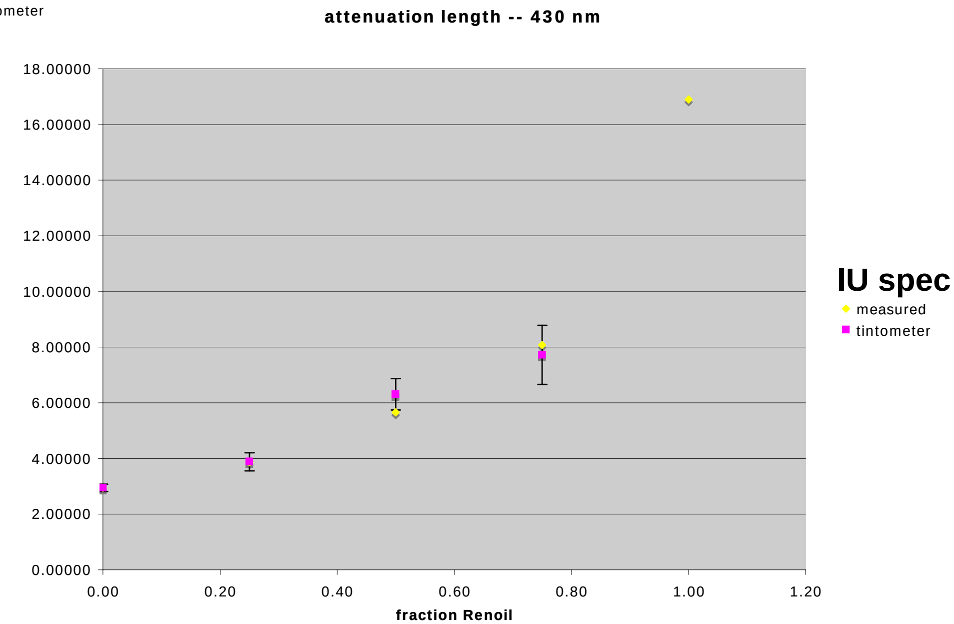


Measured attenuation length (m) of samples with IU spectometer

frac.parol	frac.renoil	410 nm	420 nm	430 nm	440 nm	450 nm	460 nm
1.00	0.00	2.09	2.50	2.95	3.64	4.10	4.81
0.75	0.25	2.77	3.29	3.86	4.76	5.56	6.17
0.50	0.50	3.95	4.81	5.66	6.63	7.70	8.93
0.25	0.75	5.98	7.65	8.08	9.77	10.61	12.15
0.00	1.00	12.10	17.77	16.90	18.86	19.38	20.43

QC -- Attenuation Length

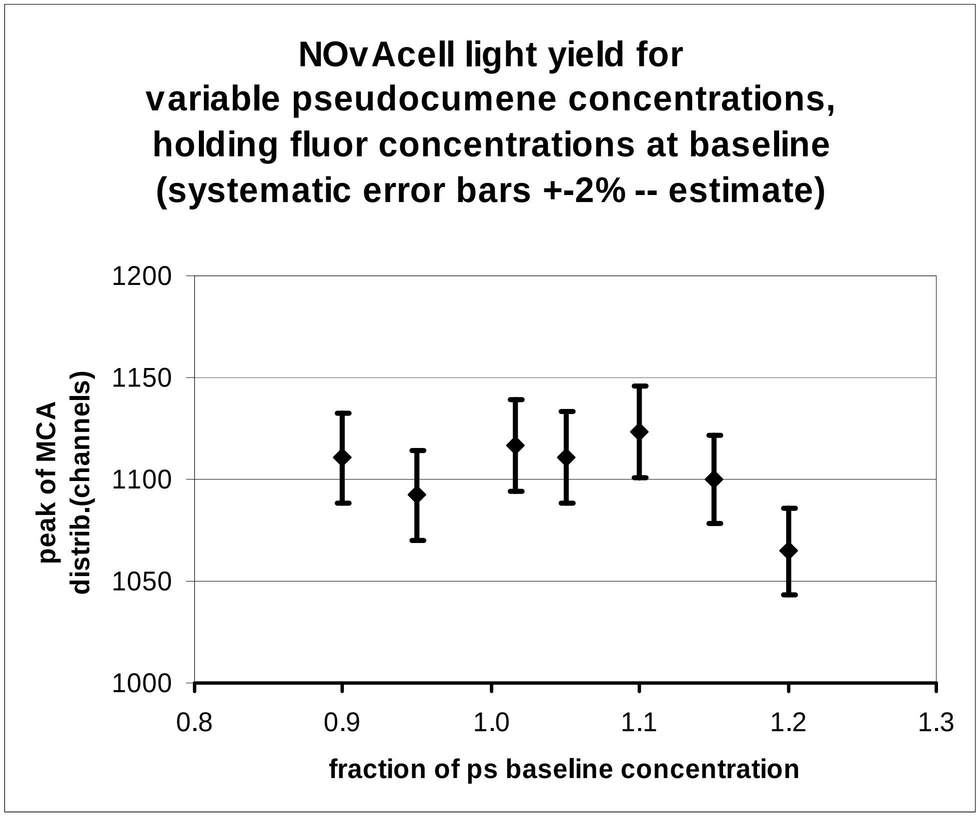




- **Method looks like it works relatively accurately out to 6m at 420nm/430nm with Parol 60C as the standard**
  - **method should work equally well for scintillator oil using Parol 60C as the standard**

Optimization

Studies are underway at Indiana to optimize the scintillator composition for performance and price



Stadis-425, Anti-Static Agent

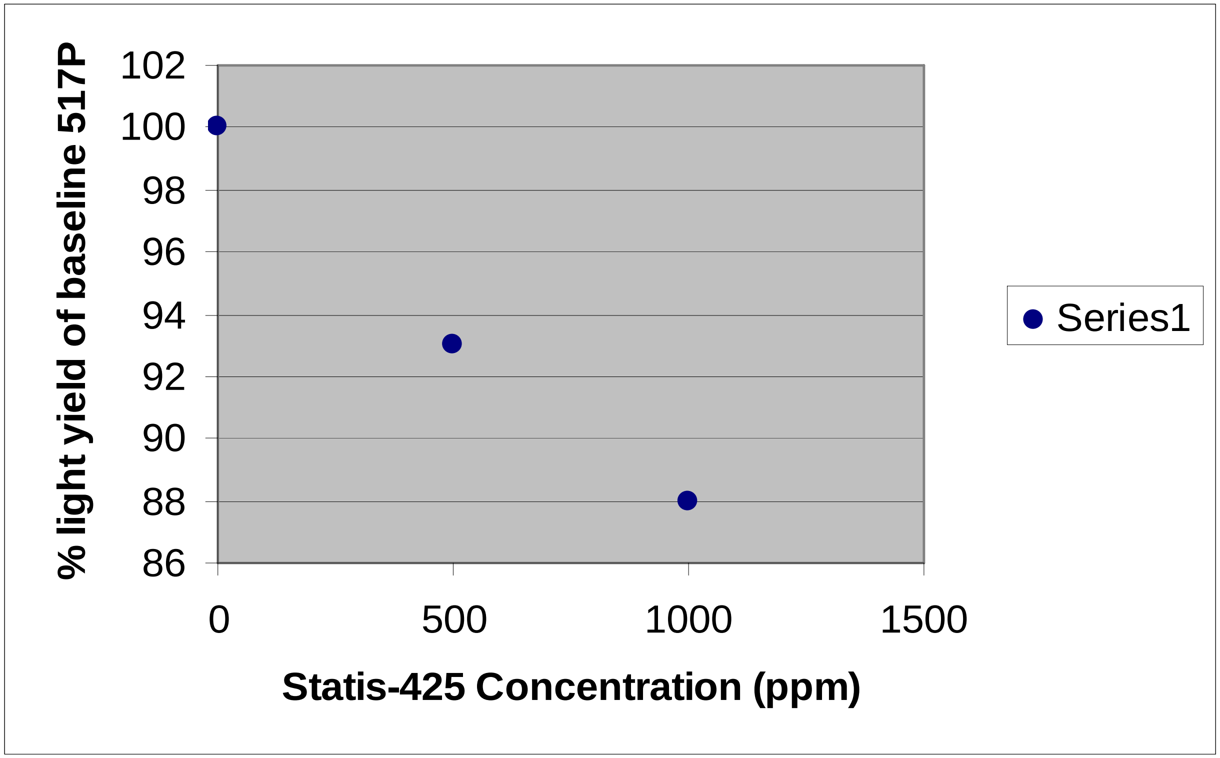
- Liquid Scintillator is extremely non-conductive. Non-conductive fluids develop a net charge through the triboelectric effect during flow, which can under certain circumstances lead to spark discharge between the liquid and container or between non-bonded plumbing components.

- Charging sources include:
  - Filters (these can result in extremely large local charge generation)
  - Pipes
  - Droplet formation in free fall of the liquid.

Mitigation

- Reduce/Eliminate ignition source (sparks).
  - Add anti-static agent (e.g. Statis-425) to scintillator to bring conductivity of scintillator up to 'safe' levels, and use conductive plumbing to provide discharge path.
  - Control of splash filling (don't allow freefall of liquid)
  - Provide discharge path in module during filling. (ground wire running down one cell)
- Eliminate fuel (aerosol or foam)
  - As noted earlier scintillator in its normal state is not a significant fire hazard. However, scintillator/air mixtures are. Hazards would be substantially mitigated if filling procedure ensures that aerosols are not created

Light Yield vs Stadis-425 Concentration



At 2ppm, there are no light yield issues with the additive
there are no attenuation length issues with the additive

Summary

- Scintillator WBS progressing toward CD2

- We understand well enough to cost by CD2:
  - the ingredients needed to produce the baseline scintillator
  - how to make the scintillator
  - how to QC the scintillator components and the blended liquid scintillator
  - how to transport the liquid scintillator to Ash River

- Issues still outstanding:
  - the optimized composition of the liquid scintillator in in terms of performance and price
  - whether the scintillator is produced at Fermilab or whether the production is done by commercial toll blender
  - development of QC procedures
  - whether Fermilab or a toll blender manages the transportation of blended liquid scintillator to Ash River